



Digging Deeper

THE CELESTIAL SPHERE

In the *Investigate*, you explored different ways of locating places on Earth. You then investigated how you could find objects in space. Locating objects in space has been a challenge for people for a very long time. For thousands of years, people from all parts of the planet recognized groups of stars in the night sky. The Greeks, Egyptians, Babylonians, and others gave names to the groups of stars. They told stories about them that allowed for their positions to be learned without needing instruments. Some scientists think that caves in France may contain drawings of the night sky from 17,300 years ago.



Figure 1 An ancient star chart showing animals and objects that represent the constellations.

Geo Words

constellation: a grouping of stars in the night sky that forms a recognizable pattern.

celestial sphere: an imaginary sphere of infinite radius that projects around Earth, and whose interior is inscribed with a grid system for taking celestial coordinates.

There are 88 groupings of stars in the sky. Astronomers call a grouping of stars a **constellation**. Each constellation has a Latin name. The name is given a three-letter abbreviation. For example, *Cassiopeia* is abbreviated as *Cas*. *Draco* is abbreviated as *Dra*. Constellations are important reference points for locating planets and other astronomical objects in the night sky.

Many ancient astronomers thought that the stars were attached to a giant hollow sphere that surrounded Earth. Astronomers now know that such a sphere does not exist. Stars are located throughout space at different distances from Earth. However, the idea of a giant sphere, called the **celestial sphere**, is useful. It provides a model on which to place and locate stars, planets, and other objects in space. The word celestial means pertaining to the sky. The difference between astronomical objects and celestial objects is that celestial objects do not include Earth.

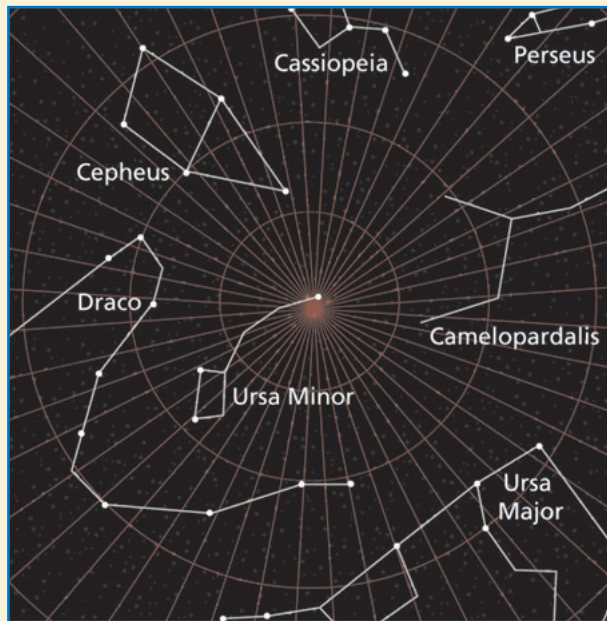


Figure 2 View of the celestial sphere looking toward the north celestial pole.

To describe the location of an object in the sky, astronomers use a special reference system. It is known as the **celestial coordinate system**. This system is similar to the one used for locating objects on Earth's surface. It uses measurements from known reference points or lines. These lines are similar to lines of **longitude** and **latitude**. The main reference line in the celestial sphere is the **celestial equator**. It is an imaginary circle created by extending Earth's equator into space.

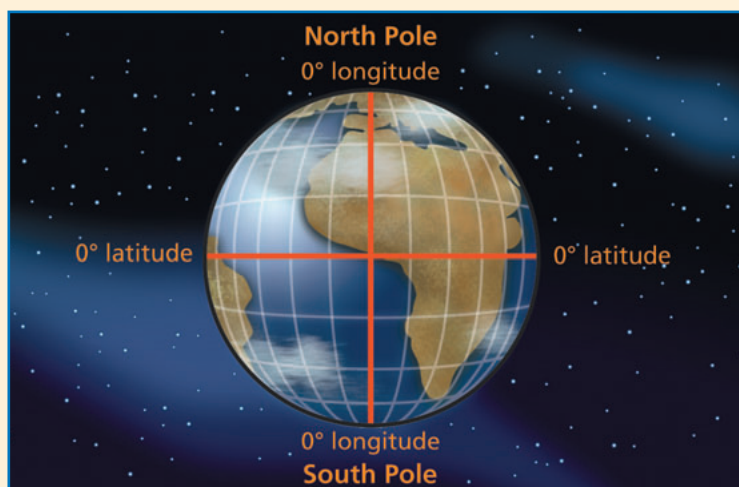


Figure 3 Locations on Earth's surface can be precisely located using longitude and latitude.

Geo Words

celestial coordinate system: a coordinate system for mapping positions on the celestial sphere.

longitude: an east-west measurement of position on Earth.

latitude: a north-south measurement of position on Earth.

celestial equator: an imaginary circle created by extending Earth's equator into space; the main reference line in the celestial sphere.



Geo Words

declination (dec): a coordinate used on the celestial sphere, just as latitude is used on Earth.

right ascension (R.A.): a coordinate used on the celestial sphere, just as longitude is used on Earth.

vernal equinox: the position of the Sun as it crosses the celestial equator into the Northern Hemisphere each spring.

The celestial coordinate system uses **declination (dec)** to measure how far north or south an object is from the celestial equator. Declination is similar to latitude. It is measured in degrees. The celestial equator has a declination of zero degrees. Objects north of the celestial equator have a positive value. Those south of the celestial equator have a negative value.

On Earth, longitude is measured east or west of the prime meridian. The prime meridian is located at 0° . It runs through Greenwich, England. Like all other lines of longitude, it runs north to south. It converges with all other lines of longitude at the poles. If you look down onto a globe at the North Pole, you can see the 360° through which Earth rotates every 24 h (hours). It rotates through an angle of 15° every hour. According to these different measurements for longitude, the city of Miami, Florida lies 80° , or 5 hours and 20 minutes, west of the prime meridian. Los Angeles, California lies 118° , or 7 hours and 52 minutes, west of the prime meridian.

In the celestial coordinate system, the lines that correspond to longitude on Earth are called **right ascension (R.A.)**. Right ascension is measured in hours, minutes, and seconds, much like lines of longitude can be measured. Right ascension is slightly more complicated to understand than longitude. Due to Earth's counterclockwise rotation, objects appear to move across the sky at night. Earth's eastward rotation causes stars to appear to move west. Thinking about the rising Moon might help you understand how this works. The Moon appears to rise above the horizon from a given point on Earth's surface. As Earth rotates, that point moves away from the Moon, which appears to rise upward and to the right. Similarly, Earth's rotation causes the positions of the stars in the sky to appear to change gradually throughout the night.



Figure 4 The trail of the rising Moon over Seattle.

In order to properly measure right ascension, a fixed point is needed. The sky lacks a fixed point. Even the stars are moving as they slowly orbit the center of the galaxy. As a result, astronomers have chosen the point on the celestial equator where the Sun crosses into the Northern Hemisphere in spring. This is a point in time known as the **vernal equinox**. Notice that this point does not coincide with the point where the prime meridian intersects the equator.

The stars seem to travel across the sky at night and the Sun seems to travel across the sky during the day. While it may appear that these objects are moving, they are not. The reason for this motion is because Earth rotates 360° about its axis every 24 hours. The points about which the sky seems to rotate are called **celestial poles**. One is located above the North Pole and the other is located above the South Pole. Over time, stars located near the celestial poles make small circles in the sky. Currently, the star called Polaris lies very close to the northern celestial pole. It therefore appears to be almost stationary in the night sky. As a result, this star has become known as the North Star or Pole Star. It has been of great use in navigation. The nearest star to the Sun is Proxima Centauri, located at right ascension 14 hours 38 minutes and declination $-60^\circ 46'$.



Figure 5 Polaris is the Pole Star seen at the center of the concentric rings in this photograph. The rings are the apparent paths of stars produced by Earth's rotation about its axis.

Not all of the stars in the sky can be seen from a single location. A person viewing stars in the Northern Hemisphere cannot see all the stars visible in the Southern Hemisphere. Some are located below the horizon. The stars that can be observed from any given place also vary throughout the year. As Earth moves around its orbit, the North and South Poles point toward different parts of the universe. As a result, different constellations and other celestial objects come into view at different times.

Geo Words

celestial pole: the point about which the sky seems to rotate.

Checking Up

1. What is the main difference between a point on Earth's grid system and one on the celestial system?
2. What is special about Polaris, the Pole Star?
3. Why do the objects you see in the sky at night change throughout the year?

Think About It Again

At the beginning of this section, you were asked the following:

- How do astronomers locate objects in the sky?

Record your ideas about this question now. Be sure that you describe the celestial coordinate system in your answer.



Reflecting on the Section and the Challenge

You used longitude and latitude coordinates to locate your school and two places of physical and historical importance on Earth's surface. Drawing your own latitude lines using a compass, protractor, and ruler helped you to understand how lines of latitude are drawn on globes and world maps. You then transferred your understanding of coordinate systems on Earth to developing a coordinate system for locating objects in the sky. You applied this new system to a model of the night sky. This will help you to describe Earth and its place in the universe for the *Chapter Challenge*.

Understanding and Applying

1. Describe the objects in the night sky above your community.
2. How do the objects you can see in the sky at night change during the year?
3. Why is it important for astronomers to make observations of the night sky from many locations?
4. Explain why you can see above and below the celestial equator.
5. Why is it that new constellations gradually enter our field of view from the east and the old ones disappear to the west?
6. *Preparing for the Chapter Challenge*

Continue developing your radio or podcast script for the *Chapter Challenge*. Explain the use of the celestial coordinate system in plotting positions in the sky. Use examples of astronomical objects to illustrate your explanation. Help your audience to understand how precisely locating objects in the sky helps to identify Earth's place in the universe.

Inquiring Further

1. **Earth's axial tilt**

Over a period of 13,000 years, Earth's axis wobbles like a spinning top. How does this affect the relative position of Polaris? Find out more about Earth's wobble, the position of Polaris, and stars that have marked the south celestial pole.

2. **Using star charts**

Get to know your community's night sky and its movements. The constellations above the horizon change with time and with the seasons. Use monthly star charts to examine the evening sky. Hold the chart overhead and turn it to match the direction you are facing. Which way do the constellations appear to move during an evening?

3. **The stories of the stars**

Different cultures give the various constellations different names and stories. Choose three constellations and recount the different cultural stories that have developed about them.